

## CLAIMS

What is claimed is:

1           1.     A method for solenoid control comprising the following steps:  
2                 providing a freewheel circuit that includes a solenoid connected to a system  
3 power supply via a resistive shunt and a freewheel diode in parallel with the solenoid,  
4 the resistive shunt being included in a current-measuring circuit that measures current  
5 through the solenoid;  
6                 providing a current-control circuit comprising a differencing component, a power  
7 transistor and a switch device;  
8                 supplying a voltage pulse to the freewheel circuit by means of said power supply  
9 to reach a predetermined current level in said solenoid, and thereafter:  
10                supplying pulsed voltage to said freewheel circuit by means of said current  
11 regulating circuit;  
12                applying a measured result from the current-measuring circuit to the  
13 differencing component and thereby maintaining the supply by means of the current-  
14 regulating circuit for a certain time based upon the result of the measured result;  
15                providing a voltage-control circuit comprising a second differencing component  
16 and having a structure similar to that of the current-control circuit;  
17                connecting an input of the second differencing component to an output of the  
18 current control circuit;  
19                applying into the freewheel circuit by means of the voltage-control circuit a  
20 control voltage of any value between 0 and a maximum supply voltage, thereby  
21 controlling the rate at which the current within the freewheel circuit decreases.

1           2. Method according to claim 1, further comprising detecting an irregularity in the  
2 decrease of the current in the solenoid during the controlled decrease of current and  
3 thereby determining when a core of the solenoid is being moved.

1           3. Method according to claim 2, in which the solenoid core moves a solenoid  
2 valve for fuel injection in a vehicle engine.

1           4.     A circuit arrangement for controlling a solenoid that actuates a valve in a  
2 fuel-injection system, in which the solenoid is connected in parallel with a freewheel  
3 element comprising:

4           a current-control circuit operable to switch current through the solenoid between  
5 a pull-in level and a hold level; and

6           a voltage-control circuit applying a continuously adjustable voltage at a  
7 connection point between the solenoid and the current-control circuit such that the time  
8 it takes the current through the solenoid to drop from the pull-in level to the hold level is  
9 adjustable above a minimum time.

1           5.     An arrangement as in claim 4, in which:

2           the current-control circuit includes an output transistor;

3           the solenoid is connected to ground over the output transistor of the current-  
4 control circuit; and

5           the connection point is electrically connected to an output point of the output  
6 transistor.

1           6.     An arrangement as in claim 5, further comprising a current-measuring  
2 circuit having an output signal indicating the current through the solenoid, the current-  
3 measuring circuit including a resistive shunt connected electrically in series with the  
4 solenoid.

1           7.     An arrangement as in claim 6, in which:

2           the output signal of the current-measuring circuit forms a first input to a  
3 differencing element in the current-control circuit;

4           a desired current level signal forms a second input to the differencing element in  
5 the current-control circuit;

6           the output of the differencing element in the current-control circuit corresponds to  
7 the difference between its first and second inputs and is applied as a driving input to the  
8 output element of the current-control circuit.

1           8.     An arrangement as in claim 7, in which:  
2           the voltage-control circuit includes an output transistor;  
3           the solenoid is connected to ground over the output transistor of the voltage-  
4 control circuit.

1           9.     An arrangement as in claim 8, in which:  
2           an output signal of the voltage-measuring circuit, which is also the signal applied  
3 at the connection point, forms a first input to a differencing element in the voltage-  
4 control circuit;  
5           a desired voltage level signal forms a second input to the differencing element in  
6 the voltage-control circuit;  
7           the output of the differencing element in the voltage-control circuit corresponds to  
8 the difference between its first and second inputs and is applied as a driving input to the  
9 output element of the voltage-control circuit.

1           10.    A circuit arrangement for controlling a solenoid that actuates a valve in a  
2 fuel-injection system, in which the solenoid is connected in parallel with a freewheel  
3 element comprising:  
4           a current-control circuit operable to switch current through the solenoid between  
5 a pull-in level and a hold level;  
6           a current-measuring circuit having an output signal indicating the current through  
7 the solenoid, the current-measuring circuit including a resistive shunt connected  
8 electrically in series with the solenoid;  
9           and  
10          a voltage-control circuit applying a continuously adjustable voltage at a  
11 connection point between the solenoid and the current-control circuit such that the time  
12 it takes the current through the solenoid to drop from the pull-in level to the hold level is  
13 adjustable above a minimum time;  
14          in which:  
15          the current-control circuit includes an output transistor;

16           the solenoid is connected to ground over the output transistor of the current-  
17 control circuit;  
18           the connection point is electrically connected to an output point of the output  
19 transistor;  
20           the output signal of the current-measuring circuit forms a first input to a  
21 differencing element in the current-control circuit;  
22           a desired current level signal forms a second input to the differencing element in  
23 the current-control circuit;  
24           the output of the differencing element in the current-control circuit corresponds to  
25 the difference between its first and second inputs and is applied as a driving input to the  
26 output element of the current-control circuit;  
27           the voltage-control circuit includes an output transistor;  
28           the solenoid is connected to ground over the output transistor of the voltage-  
29 control circuit;  
30           an output signal of the voltage-measuring circuit, which is also the signal applied  
31 at the connection point, forms a first input to a differencing element in the voltage-  
32 control circuit;  
33           a desired voltage level signal forms a second input to the differencing element in  
34 the voltage-control circuit; and  
35           the output of the differencing element in the voltage-control circuit corresponds to  
36 the difference between its first and second inputs and is applied as a driving input to the  
37 output element of the voltage-control circuit.